The Journal of Laryngology and Otology
January 1990, Vol. 104, pp. 4–8

Impedance tympanometry and the home environment in seven-year-old children

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Abstract

The distribution of tympanogram types among 872 seven-year-old children from a random population sample was related to 14 features of the home environment reported by parents in a questionnaire. Parental smoking was an important determinant of middle ear underpressure and effusion, and accounted for much of the associations observed with dampness, crowding and rented accommodation. Gas cooking was associated with a higher prevalence of effusion, but a lower prevalence of underpressure: this may deserve further study.

After adjustment for seasonal variation, tenure and household smokers, the weekly mean temperature in the bedrooms of 34 children with Type B tympanograms was 18.2°C, compared to 17.9°C for 190 children with Type A tympanograms. The equivalent figures for bedroom relative humidity were 51.8 per cent and 52.7 per cent. It is unlikely that heating or ventilation of the home is an important determinant of middle ear effusion and underpressure in this age-group.

Introduction

Little is known about the aetiology of middle ear effusion (Black 1985a), although evidence is accumulating of a substantial risk from passive exposure to tobacco smoke (Kraemer *et al.*, 1983; Black, 1985b; Hinton and Buckley, 1988; Strachan *et al.*, 1989). Studies in pre-school children have reported upon the relationship between middle ear disease and conditions in day care centres (Iversen *et al.*, 1985) and in the home (Birch and Elbrond, 1987), but no similar information has been published for children of school age. Although the overall prevalence of middle ear effusion is lower in older children, persistent effusions present a considerable burden to hospital services, and rates of surgery for glue ear are greatest in the five–seven year age group (Black, 1984).

The relationship between indoor air quality and respiratory disease in children has been extensively investigated using symptoms and ventilatory function as outcome variables. Particular areas of concern are possible hazards from suspended particulates due to parental smoking or household fires, nitrogen dioxide derived from unvented gas or paraffin appliances, and aero-allergens, such as mould spores or faeces of house dust mites, both of which tend to be more prevalent in damp houses (Samet *et al.*, 1987, 1988).

Tympanometric abnormalities are highly sensitive to frequent or persistent upper respiratory infections (Tos *et al.* 1979), and may therefore be a useful indicator of more general respiratory effects due to indoor air pollution. This paper explores the relationship between tympanometric findings and the home environment among seven-year-old children participating in a survey of the effect of damp housing upon respiratory disease (Strachan, 1988; Strachan and Sanders, 1989).

Methods

Sample selection

All children in their third (P3) year at a random sample of one in three primary schools within the Edinburgh city boundary were chosen. These children were aged 6½ to 7½ years in September 1986.

In the last week of November 1986, a postal questionnaire was sent to their parents, enquiring about respiratory symptoms in the child and conditions in the home, and including a form of consent to the remainder of the study. Children absent at the time of the launch were given a questionnaire on their return, and parents who had not responded after ten days were contacted by letter or telephone to maximize the number of replies. The parents of 1095 children received a questionnaire and usable replies were obtained from 1012 (92 per cent).

Written consent to further tests was obtained for 941 children (86 per cent of the target sample). Twenty of these children left school before examination, and two of the smallest schools (accounting for a further 20 children) were used for pilot studies of the respiratory examination protocol. The number of children eligible for inclusion in the clinical survey was therefore 901 (82 per cent of the target sample), 892 (99 per cent) of whom were eventually examined.

Ethical approval was obtained from the Paediatric/Reproductive Medicine Ethics of Medical Research Sub-Committee of the Lothian Health Board and from the Research Committee of the Department of Education, Lothian Regional Council.

Accepted for publication: 7 September, 1989.

Impedance tympanometry

Children were tested at school by the author during the period January to June 1987. Middle ear pressure, compliance, and the relative gradient of the tympanometric curve were measured on both ears using a Microlab 'Earscan' configured for impedance measurements (Micro Audiometrics, Port Orange, Florida, USA). This uses a probe tone of 226 Hz at 85 dB and sweeps from +200 to −312 daPa at 100 daPa/sec. Subjects were asked to swallow a sip of water immediately prior to the measurement, to ensure that patent eustachian tubes would be ventilated. Tympanogram types were defined on the basis of the modified Jerger classification proposed and validated by Fiellau-Nikolasen (1983):

Type	MEP (daPa)	Gradient	Interpretation
A	+200 to −99.9	>10%	Normal tympanogram
C1	−100 to −199.9	>10%	Mild underpressure
C2	−200 to −312	>10%	Severe underpressure
B	No peak	<10%	Middle ear effusion

The tympanogram type from the more abnormal ear of each child was used in the analysis. This permitted the inclusion of 23 children with satisfactory results from only one ear.

Monitoring of bedroom temperature and relative humidity

During the period January to April 1987, an attempt was made to visit the homes of 377 children, comprising all those in eight schools, those in the top quintile of the estimated bedroom humidity distribution (as described in detail by Strachan and Sanders, 1989) and the remainder of the homes reported to be affected by dampness or mould growth.

In each home, the temperature and relative humidity of the child's bedroom were monitored for seven days by thermohygrograph (Casella Ltd, London, UK). This instrument measures temperature by bimetallic strip and humidity by changes in the length of a treated human hair, and both are charted on a slowly moving drum. The thermohygrographs were installed in a position between three and six feet high and out of direct sunlight. On completion of the recording, their calibration was checked by a spot measurement of wet and dry bulb temperature using an aspirated psychrometer. The relative humidity was calculated from the wet and dry bulb thermometer readings using standard formulae (British Standards Institution, 1965).

Thermohygrograph charts were digitized for computer analysis and mean weekly values for temperature and relative humidity were calculated. Measurements were taken in 330 homes, of which 307 were usable in this analysis (81 per cent of the target sample). Technical problems with the instruments, including interference by the child or their siblings, accounted for most of the unusable recordings.

Relative humidity is a function of both vapour pressure (which reflects absolute humidity) and temperature (which determines the saturation vapour pressure at which condensation will occur). The relationship between indoor relative humidity and outdoor conditions is complex, depending upon the respective temperatures and vapour pressures. Thus, in well-heated bedrooms relative humidity was lower in colder weather, reflecting the lower outdoor vapour pressure usually found during the winter. However, in poorly-heated bedrooms the relative humidity was higher during the winter, because it was determined by the indoor temperature which varied to a greater extent with external conditions. Weekly mean indoor temperature and relative humidity measurements were adjusted for external climatic variations, as described in detail elsewhere (Strachan and Sanders, 1989).

Statistical analysis

Preliminary analyses were performed using Statistical Analysis System (SAS Institute Inc, 1985). The effect of housing conditions upon the distribution of tympanogram types was determined for 14 characteristics of the home environment reported in the questionnaire: tenure, number of persons per room, number of smokers in the household, use of gas for cooking, use of a coal fire, bottled gas appliance, paraffin heater, wood stove, presence of damp patches on walls, patches of mould or fungus, and the following characteristics of the child's bedroom during the winter months: number of children sleeping in the room, heat at night, heat during the day, and window left open at night. Most of the findings were negative, and results are presented in full only for seven variables for which an aetiological role in upper respiratory disease has been suggested by other studies. Trends in prevalence of Type B tympanograms across 2 × k contingency tables were assessed by the χ^2 statistic proposed by Mantel (1963).

The effect of housing conditions was investigated further by multiple logistic regression analysis, using the GLIM statistical package (Baker and Nelder 1978). Middle ear effusion (Type B tympanogram) was treated as the outcome variable, and those with Type A or Type C tympanograms as the comparison group. Housing tenure, domestic crowding (more than one person per room), gas cooking and dampness were treated as dichotomous explanatory variables, and the number of smokers in the household was included as a factor with three levels: none, one, two or more.

Results

Tympanometric data for the more abnormal ear of 872 children (98 per cent of those tested) were available for analysis. Overall, there were 546 Type A, 149 Type C1, 95 Type C2 and 82 Type B tympanograms. Twenty-six of the 82 children with a flat tympanogram in one ear had a flat tympanogram in the other.

Table 1 shows the distribution of tympanogram type by housing conditions, as reported in the postal questionnaire. Missing questionnaire data slightly reduced the numbers available for analysis by each housing variable. Middle ear pressure was lower among children from rented or crowded homes and from families with two or more smokers. Domestic fuels, dampness and mould growth had small or inconsistent effects upon the prevalence of underpressure (Types B and C combined), although Type B tympanograms were more common in all the 'exposed' categories.

TABLE I
Prevalence (%) of middle ear effusion and underpressure in the more abnormal ear by reported housing conditions

		More negative middle ear pressure (daPa)			
		+100 to −100 (Type A)	−200 to −100 (Type C1)	−300 to −200 (Type C2)	Negative no peak (Type B)
Tenure	own	64.6 (396)	16.3 (100)	10.6 (65)	8.5 (52)
	rent	57.8 (147)	18.5 (47)	11.8 (30)	11.8 (30)
Persons per room	<1.0	64.2 (187)	15.5 (45)	12.7 (37)	7.6 (22)
	1–1.5	62.0 (268)	19.0 (82)	8.6 (37)	10.4 (45)
	1.5+	59.8 (65)	13.9 (15)	14.8 (16)	11.1 (12)
Smokers in household	0	63.9 (292)	17.3 (79)	10.7 (49)	8.1 (37)
	1	63.3 (169)	16.5 (44)	10.9 (29)	9.4 (25)
	2+	56.4 (79)	17.1 (24)	12.1 (17)	14.3 (20)
Gas cooker	no	60.5 (221)	21.1 (77)	11.0 (40)	7.4 (27)
	yes	64.1 (320)	14.2 (71)	10.6 (53)	11.0 (55)
Coal fire	no	63.1 (511)	16.9 (137)	10.6 (86)	9.4 (76)
	yes	59.3 (32)	16.7 (9)	13.0 (7)	11.1 (6)
Dampness on walls	no	62.9 (462)	17.7 (130)	10.8 (79)	8.6 (63)
	yes	60.0 (78)	13.8 (18)	12.3 (16)	13.8 (18)
Mould growth	no	62.7 (492)	17.4 (137)	11.0 (86)	8.9 (70)
	yes	62.0 (49)	13.9 (11)	11.4 (9)	12.7 (10)

Number of children in parentheses.

The most marked difference in the prevalence of Type B tympanograms was between homes without smokers and those in which two or more adults smoked cigarettes. Overall, the trend of increasing prevalence with increasing number of smokers in the household was significant ($\chi^2 = 4.15$, df=1, $p<0.05$). The difference between owned and rented homes ($\chi^2 = 1.95$, df=1, $p>0.10$) and the trend of increasing prevalence of flat tympanograms with increasing housing density ($\chi^2 = 1.77$, df=1, $p>0.10$) could readily have occurred by chance. The prevalence of effusion was somewhat greater in the homes with damp patches on the walls ($\chi^2 = 3.01$, df=1, $0.05<p<0.10$).

There was also an excess of effusions in the homes with gas cooking ($\chi^2 = 2.81$, $0.05<p<0.10$), although the prevalence of underpressure was lower in this group. The number of children exposed to other sources of nitrogen dioxide in the home was small, but in each group the prevalence of Type B tympanograms was higher than among unexposed children: 11.3 per cent (7/62) for those exposed to bottled gas stoves, and 18.2 per cent (4/22) for children in homes with paraffin heaters.

In contrast to the effect of passive smoke exposure on the prevalence of middle ear effusion, the prevalence of pain or discharge in the ear over the past year differed little between non-smoking homes (23.5 per cent), homes with one smoker (25.3 per cent) and homes with two or more smokers (24.4 per cent). The corresponding proportions of children reported to have had tonsils or adenoids removed were 11.6, 14 and 12.1 per cent respectively. The prevalences of recent ear trouble and tonsillectomy or adenoidectomy varied little with respect to housing tenure, the use of gas for cooking, or the presence of dampness in the home (Strachan, 1988).

The prevalence of parental smoking (particularly both parents smoking) was higher in rented or crowded homes, and in homes affected by dampness or mould growth. When adjusted by multiple logistic regression for the effects of housing tenure, domestic crowding, gas cooking and damp walls, the excess of Type B tympanograms among children from homes with one smoker in the household (compared to none) was negligible (odds ratio 1.04, 95 per cent confidence interval 0.56–1.78). The effect of two or more smokers remained substantial, although of borderline significance when compared to non-smoking households (odds ratio 1.80, 95 per cent CI 0.96–3.40). The odds ratio estimates for Type B tympanograms, independent of parental smoking and other factors, were 1.28 (0.73–2.21) for rented housing, 1.05 (0.70–1.57) for domestic crowding (more than one person per room) and 1.38 (0.73–2.59) for damp patches on walls. The association of gas cooking with middle ear effusion was not confounded to any great extent by these factors, the adjusted odds ratio for homes with gas cooking being 1.40 (0.90–2.18).

The effect of indoor air quality was explored in more detail among the 307 children with tympanometric data whose homes had been visited in the thermohygrograph survey. Table II shows the mean temperature and relative humidity, adjusted for climatic variation, in groups defined by tympanogram type. There was little overall heterogeneity, and no evidence of a significant trend in bedroom temperature or humidity with degree of tympanometric abnormality. Further adjustment for housing tenure and the number of smokers in the household made little difference to these results (Table II). The mean temperature or relative humidity in each group might be misleading if the relationship between indoor conditions and middle ear disease were U-shaped, rather than linear. However, inspection of the spread of readings within each tympanogram group did not suggest that tympanometric abnormalities were more or less common at each extreme of the temperature or relative humidity distributions.

Discussion

This study has confirmed the importance of parental smoking as a risk factor for middle ear effusion, as discussed in detail elsewhere (Strachan et al., 1989). Of the remaining factors studied, gas cooking emerged as the

TABLE II
Mean adjusted weekly mean bedroom temperature and relative humidity by tympanogram type

	Tympanogram types				F statistics*	
	A	C1	C2	B	ANOVA	trend
As measured						
Temperature (°C)	17.87	17.27	17.72	18.18	2.09	0.07
Relative humidity (%)	52.70	54.99	51.93	51.99	2.18	0.23
Adjusted for tenure and number of smokers:						
Temperature (°C)	17.88	17.32	17.76	18.19	1.95	0.20
Relative humidity (%)	52.73	54.95	51.90	51.84	2.19	0.25
Number of children	190	59	33	34		

*Tests for heterogeneity (ANOVA) have 3 and 303 df. All are $p>0.05$.
Tests for trend have 1 and 305 df. All are $p>0.10$.

one with the strongest independent relationship to middle ear effusion, although it was quite likely that this association could have occurred by chance. The excess of middle ear effusions among children with unvented gas or paraffin appliances in the home was consistent with a hazard due to nitrogen dioxide exposure, although the overall prevalence of middle ear under-pressure was lower in the children from homes with gas cookers. Such a discrepancy suggests chance variation rather than a causal relationship. This is the first report upon the association between gas cooking and middle ear disease, but Black (1985b) described a significant excess of cases attending for glue ear surgery among children from homes with open gas fires or paraffin heaters, which was attributable to confounding by parental smoking and birthplace. The present results should be regarded as a stimulus to further studies, rather than conclusive evidence for or against an environmental health hazard. Such studies may need to be large, or to use direct measures of pollutant levels, since a simple dichotomy between gas and other cooking fuel is a relatively crude indicator of personal nitrogen dioxide exposure (Ogston *et al.*, 1985).

These results do not suggest that the temperature or humidity of the home environment is an important determinant of middle ear effusion in children of primary school age. However, because the study was based upon children attending school, the proportion of their time spent in the home was less than for younger children. Caution is required in extrapolating these conclusions to other age-groups. Birch and Elbrond (1987) found that both minimal and copious ventilation through windows were associated with fewer Type B tympanograms in children aged 0–6 years but no direct measurements of indoor air conditions were obtained. Their findings were based upon small numbers in each group and are difficult to interpret because copious ventilation was often associated with heavy smoking in the home.

Both high and low ambient relative humidity have been proposed as factors promoting the spread of viral respiratory infections in droplet spray (Lester, 1948; Kingdom, 1960; Buckland and Tyrell, 1962). The lack of any relationship of tympanometric findings to ambient humidity in the child's bedroom does not suggest that domestic humidity is a significant factor in the transmission or infectivity of such infections. In this age-group, however, much of the transmission by droplet spray may be expected to occur at school.

Spot measures of relative humidity at the time of examination revealed much drier conditions in schools than in children's bedrooms, with relative humidity generally below 40 per cent. A review of controlled studies of humidification in working environments by Green (1984) suggested that the incidence of upper respiratory illnesses in adults is reduced if humidity is raised above this level, perhaps because drying and cracking of the nasal mucosa reduces host resistance. It is therefore possible that indoor atmospheric conditions at school were influential in determining the prevalence of middle ear effusion in these children, despite the lack of correlation between bedroom conditions and tympanometric findings. However, Iversen *et al.* (1985) found no relationship between middle ear effusion in younger children and the temperature, relative humidity or carbon dioxide concentration in their day centre. A similar investigation among children of early primary school age would be useful. Indeed, all studies exploring the respiratory effects of indoor air quality might consider the objective and sensitive technique of impedance tympanometry for inclusion alongside more conventional disease outcomes.

Acknowledgements

Fieldwork was completed while the author held a Wellcome Research Training Fellowship, and was supported by the Asthma Research Council. The author wishes to thank the Building Research Establishment Scottish Laboratory, East Kilbride, for loan of thermo-hygrographs and for computer analysis of temperature and relative humidity charts.

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